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Systems Techniques Research

(Title Unclassified)

Consolidated Quarterly Status Report No. 33

1 July to 30 September 1962

Downgraded at 12-year Intervals
Not Automatically Declassified
DoD DIR 5200.10

QUARTERLY STATUS REPORT NO. 33
Prepared under
AIR FORCE CONTRACT AF33(616)-7944
and
QUARTERLY STATUS REPORT NO. 4
Prepared under
SIGNAL CORPS CONTRACT DA 36-039 SC-87300

SYSTEMS TECHNIQUES LABORATORY
STANFORD ELECTRONICS LABORATORIES
STANFORD UNIVERSITY · STANFORD, CALIFORNIA

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SEL-62-134

SYSTEMS TECHNIQUES RESEARCH

Consolidated Quarterly Status Report No. 33

1 July to 30 September 1962

Quarterly Status Report No. 33
Prepared under
Air Force Contract AF33(616)-7944
and
Quarterly Status Report No. 4
Prepared under
Signal Corps Contract DA36-039 SC-87300

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FOREWORD

The research reported in this document was performed under Signal Corps Contract DA 36-039 SC-87300 and Air Force Contract AF33(616)-7944*, as part of the research program in Systems Techniques of the Stanford Electronics Laboratories.

In the table of contents which follows, projects are listed in numerical order by project number (e.g., 507, 513, 514, etc.). Included in each project listing are the last two numbers (00, 44) of the applicable contract number, and a letter (U or C) denoting the classification.

NOTE ON SECURITY CLASSIFICATIONS: The classification of this document is CONFIDENTIAL. However, many projects are unclassified and the status of each is shown with the project title in the text. Unless otherwise noted, the project classification will apply as well to the reported information.

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*Work in Electron Devices performed under this contract is reported separately in the unclassified Consolidated Quarterly Status Report of Stanford Electronics Laboratories.

CONTENTS

Research is reported on)

Passive detection and location, intercept receivers and related devices, analysis techniques, adaptive applications, study and development of new systems techniques, active jamming devices, and special circuit and component investigations. AF QRC consultations.)

ILLUSTRATIONS

PROJECTS UNDER CONTRACT DA 36-039 SC-87300

PROJECTS UNDER CONTRACT AF33(616)-7944

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1 July to 30 September 1962

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PUBLICATIONS AND REPORTS OF THE
STANFORD ELECTRONICS LABORATORIES

1 July to 30 September 1962

JOURNAL ARTICLES ACCEPTED FOR PUBLICATION

R. C. Cumming, "Nonlinearity and intermodulation in high-power tuned amplifiers," Trans. IRE, Professional Group on Communication Systems.

TECHNICAL REPORTS ISSUED

Contract Nonr 225(24)

No. 2004-4: T. L. Grettenberg, "A criterion for the statistical comparison of communications systems with applications to optimum signal selection."

No. 1002-1: D. J. Nelson, "A foundation for the analysis of analog-oriented combined computer system."

No. 2004-6: C. K. Rushforth, "Communication in random or unknown channels."

No. 2003-4: G. H. Ball, "An invariant input for a pattern recognition machine."

No. 2104-2: B. Widrow and G. F. Franklin, "Papers on adaptive systems."

Contract AF33(616)-7944

No. 521-1: J. C. de Broekert and M. Crane, "A microwave receiver for instantaneous polarization measurement." (CONFIDENTIAL)

No. 806-1: (Internal Memorandum) F. Behr, "Analysis of an analog-voltage-multiplying circuit."

No. 507-2: D. J. Grace, "Signal sorting in electronic reconnaissance." (Report SECRET - Title UNCLASSIFIED)

Contract DA-04-200 ORD-1087

No. 1802-1: H. C. Casey, Jr., "Fabrication of gallium arsenide sub-nanosecond switching diode."

TECHNICAL REPORTS ISSUED (Cont'd)

Contract Nonr 225(33)

No. 40: Demetri P. Kanellakos - Report and Title SECRET.

No. 44: T. A. Croft - Report and Title SECRET.

No. 50: G. Barry, "Acoustic waves in the ionosphere." Report SECRET - Title UNCLASSIFIED.

No. 56: O. G. Villard, Jr., "Guide to the technical reports of Contract Nonr 225(33) as of April 1962."

No. 55: D. P. Kanellakos and O. G. Villard, Jr. - Report and Title SECRET.

No. 62: John Ames, "The correlation between frequency-selective fading and multipath propagation over an ionospheric path."

No. 64: George Barry, "Ray paths of acoustic waves in the ionosphere as obtained with an analog computer."

Progress Report: L. A. Roben, "Progress report on long-range radio-propagation-experiment (LRPE) program." Report SECRET - Title UNCLASSIFIED.

No. 60: T. A. Croft - Report and Title SECRET.

No. 33: T. A. Croft - Report and Title SECRET.

Contract DA 36-039 SC-85387 and Contract AF49(638)-660

No. 177-1: B. J. McMurtry and A. E. Siegman, "Direct observation of microwave-frequency beats due to photomixing of ruby-optical-maser modes."

Contract DA 36-039 SC-85339

No. 1654-2: D. J. Bartelink, "Hot-electron emission from shallow p-n junctions in silicon."

Contract Nonr 225(38)

No. 2106-3: J. D. Burroughs, "An analysis of random-parameter-perturbing adaptive systems."

Contract AF30(602)-2398

No. 773-1: U. R. Embry, "The probability of intercepting radio signals scattered by meteor trails."

Contract AF18(603)-126

No. 12: D. L. Carpenter, "The magnetosphere during magnetic storms; a whistler analysis."

VISITORS TO SYSTEMS TECHNIQUES LABORATORY

During the last quarterly period there have been technical and contractural discussions with representatives of 2 companies or divisions, and with 12 government Department of Defense organizations, involving 3 separate visits and 3 visitors from companies, and 19 separate visits and 24 visitors from Department of Defense organizations. Virtually all of the visits were on a classified basis.

In addition, the Stanford program of research in electronics was formally reviewed on August 14 and 15 for approximately 200 representatives of government contractors, and the review repeated on August 16 and 17 for approximately 100 representatives of various government agencies and representatives of universities and other nonprofit research organizations.

On September 12, 13, and 14, Stanford was host to a classified DoD Electromagnetic Warfare Symposium with approximately 400 representatives of contractors, government agencies, etc., attending.

Project 507: INVESTIGATION OF ELECTRONIC SIGNAL-SORTING TECHNIQUES [AF33(616)-7944. Project Leader: D. J. Grace; Staff: R. Lee, T. Jackson, B. Dolan, M. Warner. CONFIDENTIAL].

The purpose of this project is to make a study of (1) the philosophies and some probable applications of signal sorting, (2) circuit techniques for sorting on various bases, (3) choice of design parameters, and (4) various techniques for display and selective control of jamming.

PULSE BURST GENERATOR

Additions and modifications were made to the first draft of the final report.

ROB SIMULATION

This phase of the project was inactive this quarter.

PAPER STUDIES

Technical Report No. 507-2 by D. J. Grace, entitled "Signal Sorting in Electronic Reconnaissance," was distributed this quarter.

Project 513: ULTRALIGHTWEIGHT SIGNAL-SORTING RECEIVER [DA 36-039 SC-87300. Project Leader: R. Lee; Staff: J. C. de Broekert. CONFIDENTIAL].

The purpose of this project consists of the development of an ultralightweight receiver which analyzes radar signals on the basis of amplitude, pulsewidth, and prf, directly displaying these parameters on a peak-reading meter.

Both the S-513-1 and the S-513-2 receiver-analyzers were demonstrated at the TAC/Contractors meeting in August after having been returned by the U.S. Army Electronics Research and Development Laboratory.

It was found that the S-513-1 receiver requires a slight recalibration of its prf measurement scale. The S-513-2 receiver gave inaccurate pulsewidth readings for weak signals. Also, its threshold sensitivity control must be readjusted. These defects are now being corrected.

Project 514: SIMULTANEOUS-PULSE RECEIVER [AF33(616)-7944. Project Leader: J. C. de Broekert. CONFIDENTIAL].

This project covers the design, construction, and testing of a transistorized simultaneous-pulse receiver.

This project has been inactive the past quarter. The final report is partially prepared.

Project 517: PRF ACCEPTOR/REJECTOR [DA 36-039 SC-87300. Project Leader: T. P. Miles; Staff: J. C. de Broekert. CONFIDENTIAL].

This project covers the design, construction, and test of a video pulse-train acceptor and rejector. This unit has the function of extracting one pulse train of preset inter-pulse interval from one or more interleaved video trains. A final report is in preparation.

Project 519: EFFECTS OF PROPAGATION ON RADAR PULSES [DA 36-039 SC-87300. Project Leader: F. Behr. CONFIDENTIAL].

This project is concerned with performing a study to determine to what degree the characteristics of radio-frequency pulses are altered when transmitted over ground-to-ground and ground-to-air paths in the commonly used radar bands.

The information to be obtained includes distribution plots of pulsewidth and pulse-to-pulse change in pulsewidth of received radar signals under various conditions.

The data are gathered in the field and recorded on magnetic tape. The tape is then played back in an analog-to-digital converter connected to a computer that processes the data and provides the desired distribution plots.

The system used in measuring the data is a linear one and, consequently, has a limited dynamic range over which it will measure pulsewidths accurately. This dynamic range is 14 db of the r-f signal. Because of this limited dynamic range, in order to measure the pulsewidth of an entire radar sweep it is necessary to make several runs, each run differing in receiver amplitude range by 14 db.

Pulsewidth may be defined in various ways. The measurements thus far made have used symmetrical percentage points to define pulsewidth.

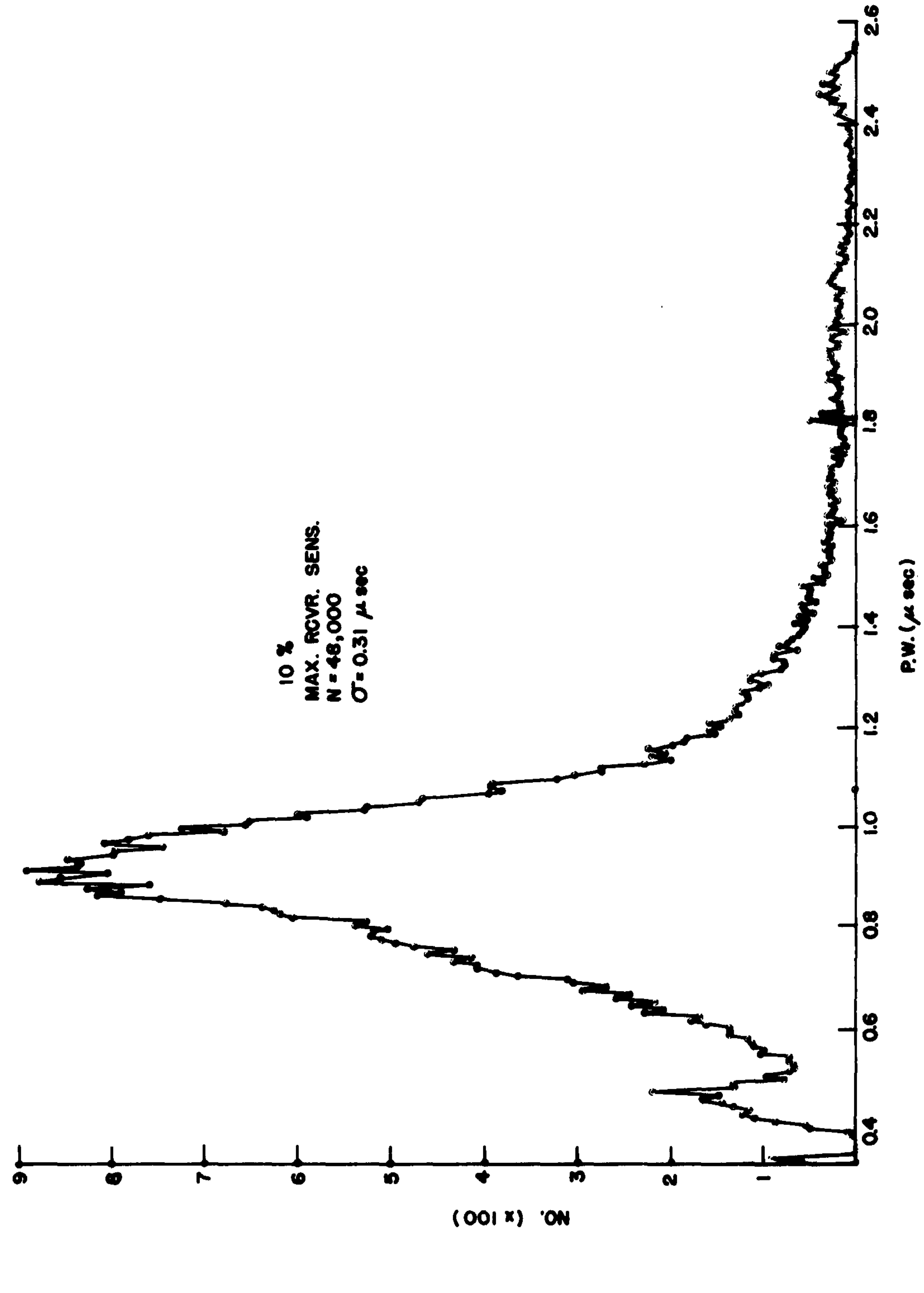


FIG. 1. PULSEWIDTH DISTRIBUTION PLOT.

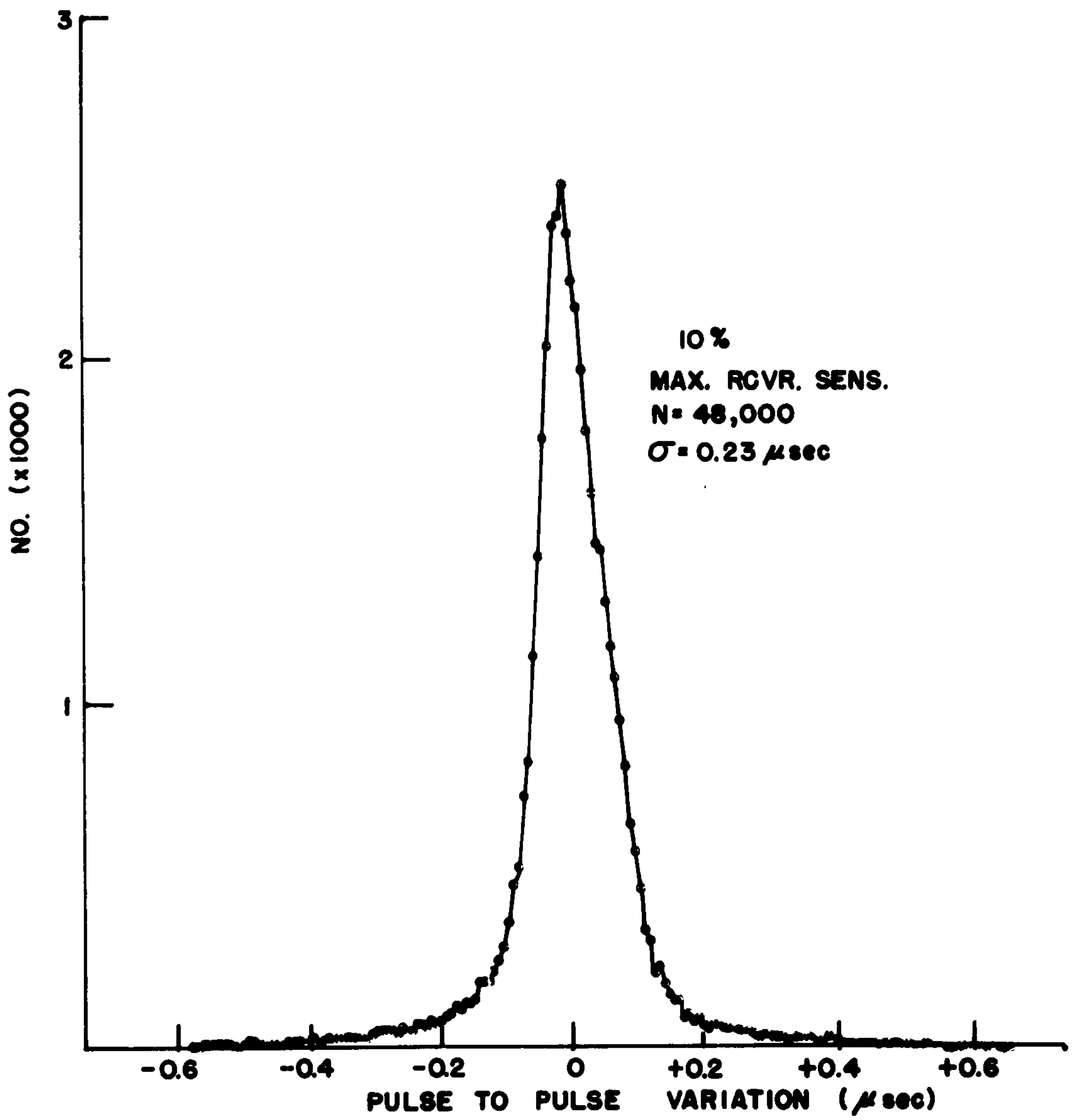


FIG. 2. PULSE-TO-PULSE VARIATION (μsec).

i.e., the measurement is made from a point on the leading edge that is some percentage of the peak amplitude of the pulse to the same percentage point on the trailing edge.

Figures 1 and 2 are examples of the two different types of distribution plots obtained. Figure 1 is a pulsewidth distribution plot of a particular radar in the San Francisco Bay Area and Figure 2 is a distribution plot of the pulse-to-pulse change in pulsewidth of the same radar. Measurements on this radar were made at the 10, 50, and 90 percentage points and at three levels of gain setting at each percentage point. The standard deviation, which is a measure of the spread of the distribution plots, was calculated by the computer. It was found that the standard deviation decreased with decreased receiver sensitivity. This would be expected since with reduced sensitivity fewer multipath reflections of the main lobe combined with direct radiations from the side lobe can be measured. It was also found that the standard deviation was greatest for the measurements made at the 10 percent points. Thus, Fig. 1 represents the worst case with the given radar: pulsewidth measured at the 10 percent level with maximum receiver sensitivity. The number of samples measured (N) was 42,000 and the standard deviation (σ) was 0.31 μsec. It can be seen that while the distribution plot has a definite peak around 0.9 μsec, some pulsewidths as high as 2.5 μsec did occur. Figure 2, the distribution plot of pulse-to-pulse change in pulsewidth, shows a relatively sharp peak. This is typical of all such plots taken to date, indicating that the pulse-to-pulse change in width was small, although large variations in pulsewidth did occur.

The analog-to-digital converter has been removed from the IBM 797 computer on which this data was processed, and combined with an IBM 1620 computer. A new program for the 1620 has been written and will soon be tested. Additional distribution plots will then be obtained on various radars in various receiver and radar locations.

Project 521: INSTANTANEOUS MICROWAVE POLARIMETER [AF33(616)-7944. Project Leader: M. Crane; Staff: E. Royer. CONFIDENTIAL].

This project covers the design and construction of an X-band receiver which can measure and display signal polarization on a pulse-by-pulse basis.

The final report is in preparation.

Project 562: MICROWAVE-SIGNAL-ACTIVITY RECORDING AND ANALYSIS TECHNIQUES [AF33(616)-7944. Project Leader: W. R. Kincheloe, Jr.; Staff: J. C. de Broekert, D. J. Iverson. CONFIDENTIAL].

A particularly simple and effective frequency discriminator technique has been devised for determination of instantaneous frequency over either a very wide or very narrow range of frequency. The arrangement employs 3 db hybrid couplers with unequal transmission lines as the frequency-sensitive element, in a manner similar to the stub technique described by B. May in TR 791-2, but with the advantage that the system is inherently matched and less sensitive to detector characteristics. The technique is immediately applicable to either a 90 or 360 degree polar display of frequency and amplitude as angular and radial deflections, respectively. A more intriguing application is in the wideband determination of instantaneous frequency as an analog voltage, which offers the possibility of signal recognition by characteristic variation of frequency with time (such as during a pulse).

Project 563: CIRCUIT APPLICATION OF NEW ELECTRONIC COMPONENTS AND DEVICES [DA 36-039 SC-87300. Project Leader: W. R. Kincheloe, Jr.; Staff: M. W. Wilkens, A. R. Moeller, H. Hewitt. UNCLASSIFIED].

The rapid development of new devices with unusual and previously unobtainable characteristics offers the opportunity for new system capability or simplified ways of attacking old problems. This project will include a variety of investigations into the application of new circuit elements and components of countermeasures and reconnaissance systems techniques.

There has been no activity during the past quarter.

Project 610: ANGULAR-DECEPTION REPEATER JAMMER [AF33(616)-7944. Project Leader: R. C. Cumming. CONFIDENTIAL].

This project was undertaken to study the feasibility of introducing angular errors into a search radar by the use of a repeater jammer. An equipment has been constructed whose function is to introduce small angular shifts in the apparent position of the target aircraft. Angular displacements in the order of one-half of the beamwidth of the radar main lobe are desired. In addition, scan-to-scan coherent side lobe jamming is utilized.

This project has been inactive the past quarter.

Project 613: INVESTIGATION OF ECM TECHNIQUES FOR THE DICKE-FIX RECEIVER [AF33(616)-7944. Project Leader: F. M. Turner; Staff: M. L. Vickers, R. C. Cumming, J. W. Goodman, J. Bradley. CONFIDENTIAL].

Further theoretical and experimental investigation of the contiguous subcarrier-barrage (CSB) jamming technique previously developed under this project will be undertaken. The object is to produce a barrage spectrum which is optimized to defeat Dicke-Fix receivers and simultaneously provide effective jamming of normal radar receivers. The barrage is to be effective against as wide a range of Dicke-Fix and normal receiver parameters as is practical. In addition, known and potential ECCM techniques which might be employed will be taken into account.

This project was inactive the past quarter.

Project 616: DUAL-CHANNEL K-BAND MONITOR RECEIVER [AF33(616)-7944. Project Leader: M. Wright; Staff: R. White. CONFIDENTIAL].

The purpose of this project is to construct a dual-channel K_u-band receiver incorporating the capability for both pulse and c-w signal reception. The receiver will use broadband, periodically focused TWT preamplifiers and transistorized log-video amplifiers. The construction will be such as to allow operation at the temperatures and pressures occurring at 80,000-ft altitude. It is anticipated that limited flight tests will be performed with the unit.

During the past quarter work on the final report has continued along with adjusting a few of the 616 circuits for best operation. The video amplifiers were not well matched as to noise and output amplitude characteristics, so adjustments have been made in order to bring these characteristics closer together. At the same time, a small blower has been ordered to help the localized heat problem which has arisen in the high-voltage power supply regulator circuit.

The cables on the traveling-wave tubes were slightly long. During the shortening operation a defect was discovered in the cable of one of the tubes which requires correction by the TWT manufacturer. Since this defect could possibly cause voltage breakdown in the cable at low atmospheric pressure, it must be corrected prior to any equipment flight or environmental testing. There is a possibility that this unit will be flown in the near future in an unpressurized aircraft compartment. Therefore, any possibility of voltage breakdown at low atmospheric pressure must be removed.

The final report will be finished and possibly issued during the next quarter. Flight tests results will probably not be included but can be issued as a separate report at a later date.

Project 618: PULSE-COMPRESSION RADAR COUNTERMEASURES STUDY [AF33(616)-7944. Project Leader: B. May; Staff: M. Gillis, R. McCoy. CONFIDENTIAL].

The primary objective of this project is the determination of the jamming vulnerability of pulse-compression radars. However, the radar signal and receiving system that might be encountered will play an important part in the jamming considerations. Thus, a secondary objective is the investigation of possible radar signals and receivers.

The code study of this project has been reactivated with the addition of R. McCoy to the staff. At present, a unification of existing computer programs is being made so that the techniques of truncation, permutation, and bit changing can be accomplished in a logical manner. Previous results in searching for good radar codes with these methods included a 127-length code with a side-lobe level of 8. This is sufficiently encouraging to continue with the same approach.

A study is being made of radar receivers employing Wiener filtering methods for optimum resolution and accuracy. The Wiener filters are derived by minimizing the mean-square error between the filter output and a desired output. The advantage of these filters in comparison to matched filters lies in the suppression of both the self-interference of signals and the additive noise interference. As the input signal-to-noise ratio approaches infinity, the Wiener filter becomes an inverse filter which estimates the location of targets with absolute accuracy, and the resolution problem is nonexistent. As the signal-to-noise ratio approaches zero, the filter reverts to a matched filter which maximizes output signal-to-noise ratio.

Project 708: APPLICATIONS OF VARIABLE-PARAMETER CIRCUIT ELEMENTS [DA 36-039 SC-87300. Project Leader: D. J. Grace; Staff: J. McConnell and R. W. Newcomb].

This project is a theoretical and experimental investigation of applications for variable-parameter circuit elements.

The principal objectives of the current activities are briefly summarized by the topic designation "Theory and Design of Nonlinear Reactance Subharmonic Generators". This title will be substituted in subsequent reports. The desired result of these efforts is an organized theory which would be of significant help to a designer who wishes to use nonlinear reactance(s), e.g., back-biased junction diodes, to generate a given subharmonic of some sinusoidal input voltage or current. It is hoped at present that useful results can be obtained without developing the actual solutions (either exact or approximate) of the nonlinear differential equations involved, since such solutions are at best very difficult and tedious. That is, perhaps one can proceed directly to the design phase of the problem, given only the nonlinear characteristic of the reactance and the type, frequency, and magnitude of the driving function.

Several aspects of the problem are being considered. These include:

1. Existence of Subharmonic Response. This includes characterization of the device. Once the characterization is accomplished and a circuit configuration is chosen, the differential equation is determined and the

conditions for existence of a given response must be determined from the theory of nonlinear differential equations.

2. Possible Circuit Configurations. This is intimately related to aspect 1. Attention will probably be limited to one-degree-of-freedom circuits, with the possible exception of certain other circuits which contain a simplifying symmetry.

3. Optimization of Design. This includes a consideration of how the optimum design should (or might) be defined.

Other topics which may be considered are the use of a time-varying (rather than nonlinear) element and the effects of loss in the nonlinear reactance.

Most of the effort to date has been centered on aspect 1, with the immediate objective that of finding stable approximate solutions, for a simple circuit configuration and nonlinear characteristic, which contain subharmonic term(s). Attention is at present being given to a numerical analysis approach using a digital computer. It appears very likely that each different subharmonic requires treatment as a separate problem; that is, the nonlinearity of the problem precludes any "general" solution for an nth-order subharmonic. Once such solution(s) are obtained, it is hoped that the form of the solution can be more or less directly related to the circuit parameters.

This effort will be continued, and in the near future specific attention will be given to aspect 2 and to the definition problem in aspect 3.

Project 709: CATHODE-RAY INSTANTANEOUS-FREQUENCY METER [DA 36-039 SC-87300. Project Leader: R. C. Cumming; Staff: H. Schmid. UNCLASSIFIED].

The purpose of this project is to construct and test a cathode-ray-deflection device which is actuated directly by an r-f signal. No detectors or balanced amplifiers are required. The visual display is a straight line whose slope is a measure of the instantaneous frequency of the r-f signal. The basis of frequency discrimination is transit-time effect in the region of the cathode-ray deflection plates. The theory of operation and measurements on an experimental tube are described

in TR Nos. 709-1 and 709-2, and in the Proceedings of the IRE for February 1962, pp. 221-222.

A report (to be numbered 709-3) is being prepared on possible ways to increase the sensitivity of the frequency meter. The following principles are described in detail therein:

1. Longitudinal connection of the deflection plates, permitting minimum plate separation with 50-ohm plate impedance. The input and output connections of a plate pair are made at the gun and screen end of the plates, respectively. This makes the impedance independent of the plate separation, which can be reduced to the value required to prevent interception with design screen-deflection. In contrast, the first model of the frequency meter used a transverse connection, with the signal entering and leaving the plate region in the middle of the plates.

2. Use of small beam diameter to increase the sensibility, i.e., the deflection in beam diameters per watt of signal power. The useful reduction of the diameter is limited by the decrease in display brightness resulting from the smaller beam current. Post-deflection acceleration will be used to partly offset this drawback.

3. Use of a radial d-c electric field to increase an initially small deflection. The radial field is created by a "needle" electrode, extending inward for about two inches from the center of the screen, and a concentric band of Aquadag on the tube envelope. Because the field strength increases toward the center, weak signals theoretically will be deflected more than strong ones. With a strong enough field, this fact will cause an inversion of the display pattern. However, since this display distortion is entirely radial in nature, the ability to indicate frequency should not be impared.

4. Use of "scan magnification" employing an electron-transparent wire mesh and a post-deflection accelerating field to form a divergent electron lens. This lens is located between the deflection plates and the screen.

5. Use of fiber optics. Two types of fiber optics appear to be particularly applicable to cathode-ray tubes: (1) nonmagnifying face plates for contact photography to increase photometric gains up to 100

times over those realizable with conventional optics, and (2) magnifying optics to enlarge a small, high-resolution display pattern. Optics with magnification factors up to five have been made.

The new model of the frequency meter will incorporate the first four of the above principles. The construction of the new tube is expected to be completed during the next quarter.

Project 710: JAMMING COMPATIBILITY STUDY [AF33(616)-7944. Project Leader: R. C. Cumming; Staff: J. W. Goodman. CONFIDENTIAL].

A large number of different radar counter-countermeasures, or "fixes", have reached an advanced state of development. Similarly, jamming techniques specifically designed to circumvent each particular radar fix have received considerable study in various laboratories. Less attention has been devoted to jamming methods for combating several fixes simultaneously; the investigation of such methods is the subject of the present project. Examinations will be made of various radar fixes and other CCM schemes, e.g., passive jammer locators, as well as of suitable jamming techniques.

The final report is in process of publication.

Project 712: 400 - 1500 Mc RECEIVER TECHNIQUES [DA 36-039 SC-87300. Project Leader: M. Crane; Staff: P. Leal. UNCLASSIFIED].

The purpose of this project is the investigation of advanced components and circuit techniques applicable to lightweight, low-drain receivers.

Investigation of both UHF transistor amplifiers and oscillators has been in progress this quarter.

Some improvement has been made on the amplifier reported last quarter. At one point the adjustment in bias and r-f matching resulted in 16 db of gain. Further effort is being made to increase the center frequency from 1.050 Gc to 1.4 Gc and higher.

The UHF oscillator is intended to be used as a local oscillator in a wideband receiver. The goal is to make the oscillator tune over a wide frequency range electronically with an output power of 1 to 2 mw. The frequency range decided on was 2 to 3 Gc, since it is intended to

use it in a simplified broadband receiver. This range is sufficiently high to test the upper frequency characteristics of the best experimental UHF transistors.

The schematic diagram of the oscillator is shown by Fig. 3.

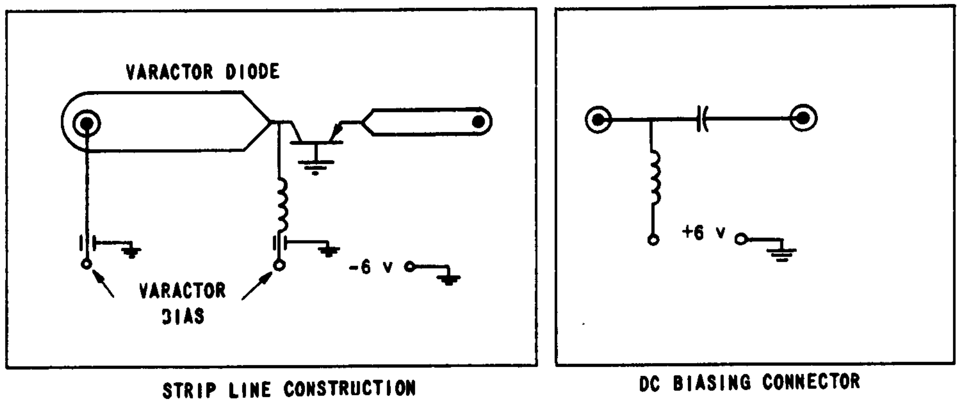
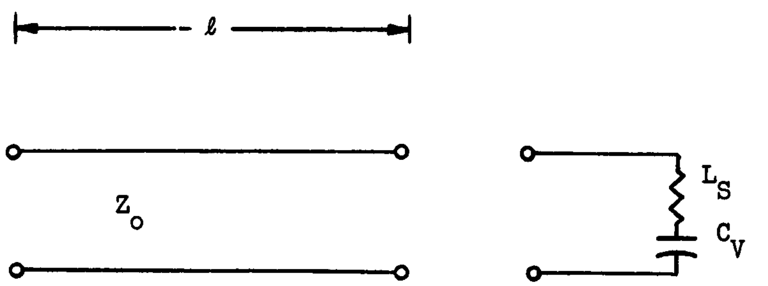


FIG. 3. SCHEMATIC DIAGRAM OF OSCILLATOR.

The distributed resonant circuit consists of a length of stripline terminated in a varactor diode. The analysis of the resonant circuit, without considering the output impedance of the transistor, is as follows:



transmission line varactor diode

for resonance

$$Z = - j\, Z_o \cot\left(\frac{\omega \ell}{v}\right) + j\left(\omega L_s - \frac{1}{\omega C_v}\right) = 0$$

$$C_v = \frac{1}{\omega\left[- Z_o \cot\left(\frac{\omega \ell}{v}\right) + \omega L_s\right]}$$

where

$$\omega = 2\pi f$$

$$v = c/\epsilon$$

The values of C_v have been computed on a Burroughs 220 computer for various practical values of Z_o, L_s and ℓ over the desired frequency range. A number of plots have been made using these data as an aid to further design work. Presently available varactors can be found with values of L_s and C_v that can be used to tune the circuit over the frequency range. A plot of the varactor parameters is shown in Fig. 4, indicating how to arrive at a choice of diodes from known technical data.

The matching of the transistor which contains a finite amount of output capacitance will be done empirically. The stripline circuit is now being constructed.

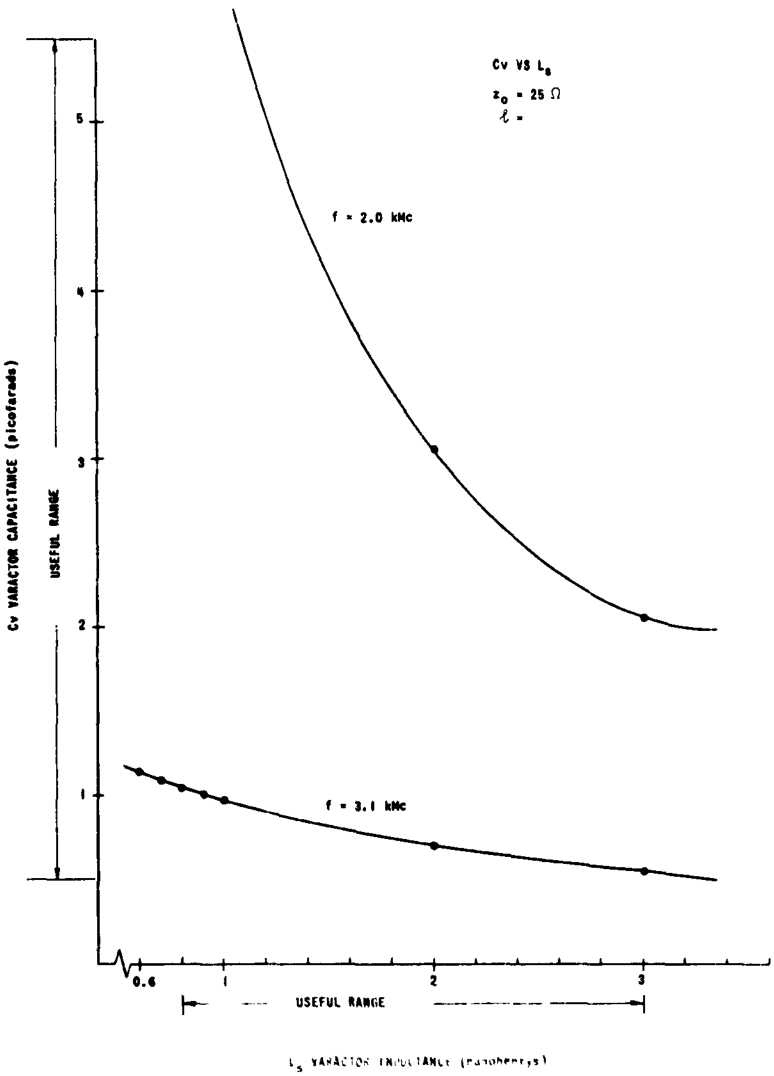


FIG. 4. PLOT OF VARACTOR PARAMETERS.

Project 713: TRANSISTOR CIRCUIT STUDIES [DA 36-039 SC-87300. Project Leaders: R. C. Cumming and M. M. McWhorter.] UNCLASSIFIED

This project includes a number of topics which are reported individually because of their diverse character. They are identified by numbers associated with a particular research group, which has as its aim initial investigations of the utilization of transistor circuitry in various systems applications. The following number (713) indicates the source of support to be that of the over-all Project 713.

Project 1613-713: A STUDY OF THE CLASS C APPLICATIONS OF POWER TRANSISTORS AT HIGH AND VERY HIGH FREQUENCIES (Staff: Robert Ward and M. M. McWhorter).

The object of this project is to find ways of characterizing transistors for Class C power amplification and to establish suitable analysis and design procedures. This will allow prediction of and design for power gain, output power, and efficiency and optimization for best over-all operation. It should also lead to a better knowledge of the desirable device properties.

Because the circuitry required to simulate the two-lump excess charge density transistor model turned out to be rather formidable, no attempt was made to do a complete two-dimensional simulation. Instead, in order to demonstrate the validity of the approach, a 2N1506 was represented by a single two-lump simulation. This was operated as a simulated 5-Mc Class C amplifier and in a switching circuit. The time scaling of 500:1 allowed simple recording techniques to be used. The results verified the use of the analog.

The final report is in preparation.

Project 1614-713: APPLICATIONS OF SWITCHING CIRCUITS (Staff: M. Swiontek).

The purpose of this project is to study the concept of sampled systems to the end of the development of refined applications of this technique.

Through various methods of analog-to-digital and analog-to-analog conversion, it has been shown to be possible to realize the set of all algebraic functions, both rational and irrational, and also

certain transcendental functions. To demonstrate the method developed through this study, the realization of the logarithmic function follows.

The system shown in Fig. 5 is not a continuous system, but rather samples the input at prescribed intervals. The logarithmic converter

FIG. 5. LOGARITHMIC FUNCTION GENERATOR.

is the portion of the system which is of interest here. To facilitate the discussion, the amplitude sample is assumed to be greater than one volt.

Any number N can be written as a base b raised to some positive power x_n, where b is assumed to be greater than 1. The number x_n is defined as the logarithm of N to the base b.

$$N = b^{x_{1s} + x_{2s} + x_{3s} + \dots + x_{ms}} = b^{x_n} \tag{1}$$

$$\frac{N}{(b)^{x_n}} = 1 \tag{2}$$

In effect, the method of logarithmic conversion consists in the realization of this latter identity.

The number x_n is composed of the digits $x_{1s}, x_{2s}, \dots, x_{ms}$ in which x_{1s} is the ones digit, x_{2s} is the tenths digit, etc.. Division of N by the greatest factor of the form, $10^{x_{ks}}$, contained in N always gives a quotient in the range 1 to 10. Therefore, to obtain the logarithm of N, an ordered division process and subsequent comparison of the quotient to one suggests itself.

To perform this process, a series of voltage dividers are necessary. The output of the first divider forms the input to the second divider, and so on. All comparisons are made to a one-volt level. The network required to perform this division is shown in Fig. 6. The voltage level

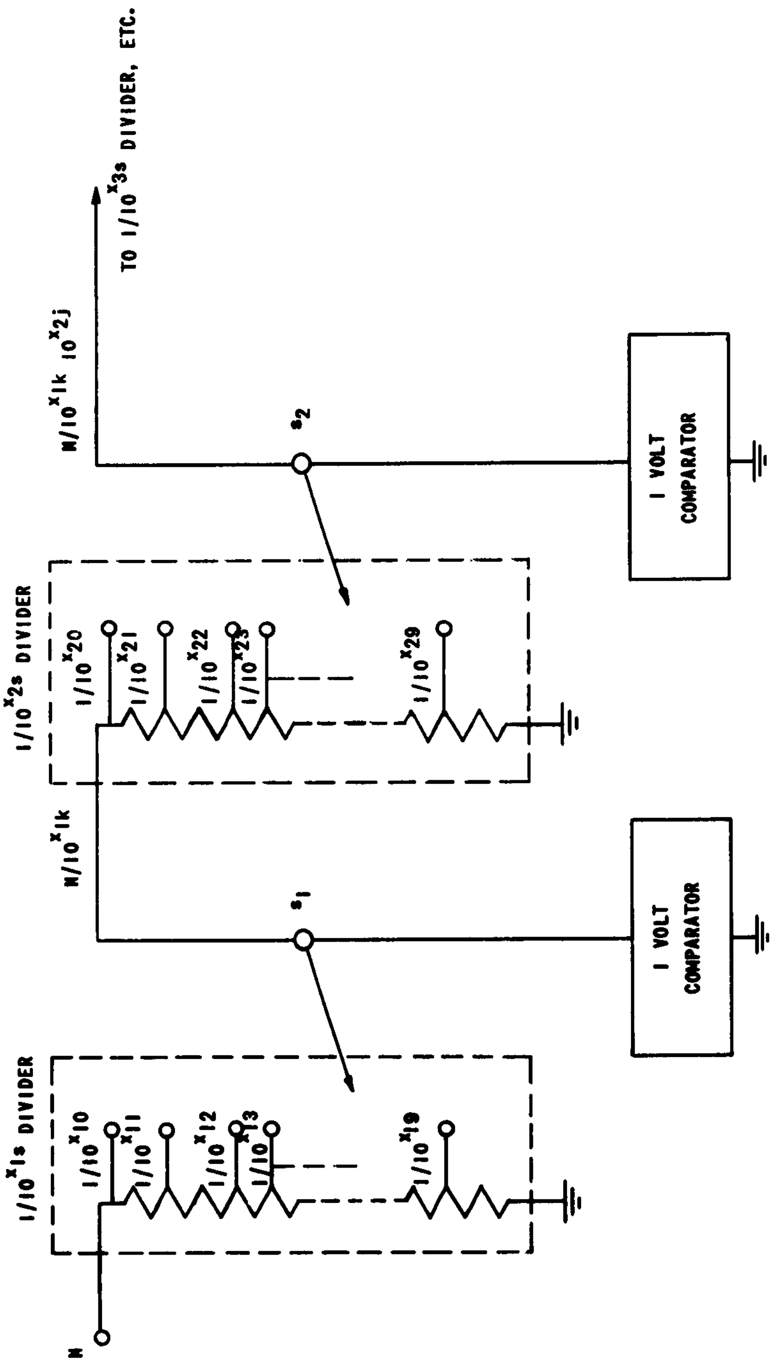


FIG. 6. NETWORK REPRESENTATION OF LOGARITHMIC FUNCTION GENERATOR.

N is applied to the $10^{x_{1s}}$ divider. This voltage level is sequentially divided by closure of one contact at a time beginning with the largest division ratio and proceeding to the lesser ratios on the $10^{x_{1s}}$ divider. As soon as the ratio $N/10^{x_{1s}}$ exceeds unity, the searching process is halted, in that $10^{x_{1s}}$ position and initiated in the $10^{x_{2s}}$ divider on the input $N/10^{x_{1s}}$ where the appropriate value of s was selected through the previous division-comparison technique. This process could be repeated until all the factors of the input amplitude are obtained. At that point, Eq. (2) will be satisfied exactly. Knowledge of the appropriate switch closures involved in satisfying the above relation yields the logarithm of N to the base 10 to the desired accuracy.

If an analog output is desired, each switch position can be made to correspond to a current or voltage equal to the magnitude of the exponent represented by each division. This current can be used to form a PAM signal which, when appropriately filtered, will yield the logarithm of the input signal in a continuous form.

The number of dividers necessary to obtain the logarithmic output can be reduced by incorporating a logarithmic diode into the system. In performing the division process on the input signal, the output of the last divider is restricted in amplitude to a very narrow range. By converting this voltage to a current, the logarithm of this current can be obtained by observing the voltage across a diode. A network which incorporates this feature, as well as presents the logarithm as a PAM signal, is shown in Fig. 7. The over-all accuracy of the logarithmic function, as well as the number of usable decades for logarithmic conversion, is greatly enhanced by this method.

The general methods illustrated here can also be extended to perform other nonlinear operations. By suitable extension of the methods as applied to sampled systems, these nonlinear functions are also realizable for a continuous system.

Since a nonlinear operator serves as a frequency spectrum expander, the various bandwidth mutations of these functions have been studied. The goal of the study was to form a concrete basis for the determination of the minimum sampling frequency while maintaining the desired over-all system accuracy.

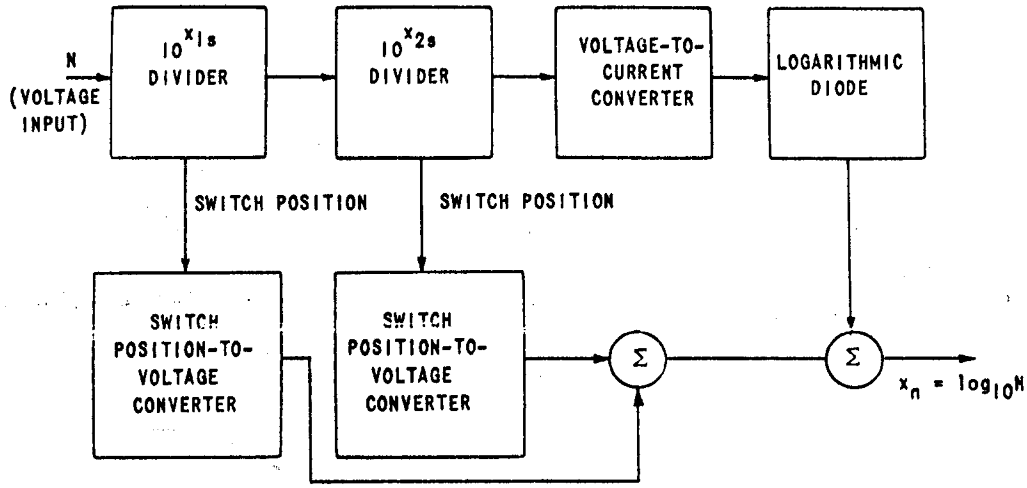


FIG. 7. PRACTICAL LOGARITHMIC CONVERTER.

Project 714: HIGH-FREQUENCY DIRECT-WRITING OSCILLOGRAPH [DA 36-039 SC-87300. Project Leader: R. G. Sweet; Staff: C. K. Liu, H. A. Berkheiser. UNCLASSIFIED].

This is a project for investigating a high-frequency recording technique in which a permanent record of the input signal is produced by an electrostatically deflected jet of ink which is directed at the recording surface. The ink jet, which typically has a diameter of 0.001 inch, is broken into discrete drops that are each electrically charged in proportion to the amplitude of the signal to be recorded. An electrostatic deflection system exerts a transverse force on the drops after they have been formed and charged. The trajectory of each drop between the jet-forming nozzle and the recording surface is a function of its charge, and thus a permanent record of the input signal is produced. The frequency response of the system is limited only by the rate at which the drops are formed, and is not dependent on the transit time through the deflection system, since a d-c transverse deflection field is used. Ink drops are typically formed at rates between 50 and 200 kc.

It has been found that air resistance causes a deceleration of the drop stream, and that this effect severely limits the nozzle-to-paper

distance that may be used, and causes distortion of the recorded signal.

A recording system has been completed in which the ink jet is injected into an air stream that flows with the ink stream in order to reduce the variation in air resistance. Jet velocity is typically 60 feet per second and air velocity may be varied between zero and this value. Distortion due to air drag is greatly reduced by the air stream, but some residual distortion remains which is caused by turbulence is the moving air. The magnitude of the turbulence increases with air speed, resulting in an optimum air speed for minimum distortion that is considerably less than the jet speed. Study and tests indicate that at least a significant part of the turbulence is caused by irregularities in the walls confining the air stream, and from the nozzle and charging electrode supports. Turbulence due to these sources could be greatly reduced in a new design.

It has been found that the charge on an ink drop is influenced by the charge of the drop preceding it, and that the resulting transient step response has an overshoot. A compensating network has been designed and is being constructed which combines the input signal with a signal delayed by the ink drop period.

Project 752: LABORATORY CONSULTATION ON AIR FORCE QRC PROBLEMS [AF33(616)-7944. Staff: T. P. Miles. CONFIDENTIAL].

The pulse Coincidence Detector described in the last QSR has been tested at Forbes AFB in a very high signal density environment. Although the circuits functioned properly, it was found that the simple functional approach used was not well adapted to this unexpectedly high signal density.

The main shortcoming was a high false alarm rate on the approximate coincidence output. It is suspected that this might be due largely to the "walk-through" problem of pulse trains which are almost synchronized.

While a detailed analysis has not been made, the probability of coincidence between individual nonsynchronized pulses is relatively high in a dense signal environment. This probability is further increased as a result of the tendency for PRF's to be clustered around particular frequencies.

Project 757: EXPERIMENTAL EVALUATION OF RECEIVERS AND RECEIVER COMBINATIONS [AF33(616)-7944. Project Leader: M. Wright; Staff: R. White. CONFIDENTIAL].

The purpose of this project is to provide experimental data, as the occasion arises, on receivers that have been developed at Stanford. Comparison of various combinations of receiver components, tests to determine applicability for special jobs, and evaluation under varying field conditions, are all anticipated objectives.

A final report, TR 757-2 entitled "An improvement program for the AN/APS-54 warning receiver," by M. Wright, is in process of publication. This project will close with the issuance of that report.

Project 770: TRANSHORIZON TROPOSPHERIC PROPAGATION [DA 36-039 SC-87300. Project Leader: A. T. Waterman, Jr.; Staff: D. B. Coates, C. Liston, J. Strohbehn, R. W. Lee, M. Hird, R. Cropek, H. Nurse. UNCLASSIFIED].

The phased-array receiving antenna is utilized as the key equipment in an experimental analysis of signals propagated over distances exceeding line-of-sight. Use of an array permits the rapid scanning of a narrow beam at a fast repetition rate. Thus, the received signal can be examined as regards its instant-to-instant variation in angle-of-arrival, and the deviating effects of the atmosphere are sampled in rapid succession. To this angle-scan type of measurement a synchronized frequency sweep has been added. Consequently, the angle variations can be examined as a function of frequency.

The complete transmitting and receiving systems were checked out both independently and together. The final test was a run for a few hours on a line-of-sight path between Niles and Stanford while duplicating all conditions present in a beyond-the-horizon experiment between Jackson, California, and Stanford. The results were recorded on magnetic tape and will be used for calibration purposes.

On 1 August through 3 August a 48-hour continuous experiment was completed between Jackson and Stanford. The data, recorded on magnetic tape, are currently being analyzed. The analysis program consists of the following:

1. Film records to give a qualitative feel for the phenomena involved.

   (a) A-scan display of the c-w signal vs azimuth (reveals fast motions in the angle-of-arrival).

   (b) Intensity modulation of angle-of-arrival data (reveals long-term motions in angle-of-arrival).

   (c) Intensity modulation of synchronous frequency sweep data (reveals variations with frequency of angle-of-arrival data).

2. Amplitude distributions measured by special counting circuitry. (Reveals variations in distributions with angle and average beamwidths.)

3. Computer analysis to give measure of statistical quantities.

   (a) Time correlation at a single frequency and angle.

   (b) Frequency correlation at a given angle.

At present, Steps 1 and 2 are well under way. The computer analysis awaits the completion of the programs that are currently being written for the IBM 1620.

This last test incorporates certain improvements over previous ones. First, the system was completely calibrated and, hence, the results may be accurately interpreted. Second, extensive weather data were also acquired, allowing correlations between weather and various experimental results to be obtained.

The calculations based on partial reflections of radio waves from atmospheric layers of small discontinuity have been completed and are presently being put in report form.

Project 801: MICROWAVE-FREQUENCY-DISCRIMINATOR TECHNIQUE [DA 36-039 SC-87300. Project Leader: R. E. Miller. CONFIDENTIAL].

The purpose of this project is to develop a 100-Mc-wide microwave-frequency discriminator capable of resolving frequency on an individual pulse basis to an accuracy of 1/5 to 1/10 of the discriminator bandwidth. Such a discriminator would find application in microwave i-f traveling-wave-tube intercept receivers intended for detection of radar signals under conditions that require relatively high sensitivity, high

probability of detecting the signal in a short time, and an ability to read the frequency to about 10 Mc.

This project will close with the issuance of final report TR No. 801-1, "An S-band microwave frequency discriminator," by R. E. Miller which is now in process of publication.

Project 804: APPLICATION OF TRANSISTOR CIRCUITS TO A 0.5 - 20 Mc INTERCEPT AND D-F EQUIPMENT [DA 36-039 SC-87300. Project Leader: T. H. Pedersen; Staff: P. Brunetti. UNCLASSIFIED].

The intent of this project is to isolate specific transistor-circuit problem areas in the AN/PRD-5 receiver and either develop circuit techniques aimed at solving these problems, or point out further advances necessary in the state of the transistor art to obtain performance consistent with Signal Corps application requirements. In addition, specific circuit design studies associated with the receiver under construction on Project 807 will be included in this project.

An 11-foot whip antenna was installed on the S-807 this quarter. This antenna is detachable and can be replaced with a less cumbersome 3-foot whip when maximum sensitivity is not required. The complete antenna installation consists of:

1. Construction of an insulated antenna receptacle.
2. Bracing the left front corner of the receiver chassis.
3. Addition of an antenna trimmer.
4. A new "ANTENNA-50 OHM" switch.
5. Reconstruction of the double-tuned preselector.

Intermodulation tests also conducted this quarter indicate that an improvement of the 5-mv overload threshold of the S-807 can be obtained by the use of the diode AGC networks when the receiver is tuned to signals greater than 1 mv. For signals less than 1 mv the intermodulation overload threshold is limited by the dynamic range of the r-f tuner and is approximately 0.005 v.

A rough draft of the final report on this project has been completed. Some final modifications of the S-807 will be carried out under this project next quarter.

Project 806: AN INVESTIGATION OF COLOR AS A CRT DISPLAY PARAMETER [AF33(616)-7944. Project Leader: W. H. Huntley, Jr.; Staff: P. Brunetti, S. Shepard. CONFIDENTIAL].

The purpose of this project is to investigate color as a display parameter, both qualitatively and quantitatively. Particular emphasis is to be placed on determining the types of systems for which color displays might be considered a necessity, in order to convey adequately the information output of the system on a single-screen display.

Objectives of the work during this quarter included: publishing the reports; completing work on the analog color converter; and starting preparation of the final project report.

The report on the analog multiplier has been published. Shortage of programmer time, which continued into this quarter, delayed analysis of the flight-test data sufficiently that the data were finally sorted entirely by hand. The flight-test report should be published early during the coming quarter.

The S-805 Color Display Unit was rebuilt to take a new, larger color tube. External characteristics of the unit are essentially unchanged, but considerable internal relocation of chassis and mounting panels was required to convert from a metal envelope tube with a 7-1/4 in. diameter viewing face to an all glass tube with a 9-in. useful screen diameter. In addition to the larger screen, the new tube provides greater brightness and much improved color mixing capability.

Work on the analog color converter was completed with construction of a test-pattern generator board. Two sweep outputs are combined to synthesize the illusion of a cube on the screen, with the three visible faces of the cube illustrating the three colorimetric dimensions of hue, saturation, and brightness. A memorandum technical report will be written on the design of the analog converter.

Objectives of the work during the coming quarter will be to complete publication of the flight-test report, prepare the analog converter memorandum, and complete the draft of the final report. This project will close with the issuance of the final report.

Project 807: TRANSISTORIZED INTERCEPT RECEIVER [DA 36-039 SC-87300. Project Leader: T. H. Pedersen; Staff: P. Brunetti. UNCLASSIFIED].

The purpose of this project is to design and construct an experimental transistorized intercept receiver for the frequency range of 0.55 - 20 Mc. With the exception that no d-f capability will be provided, the primary concern will be to produce a receiver with the electrical performance as outlined in Section 3.11 of the Signal Corps Technical Requirement No. SCL-5062.

Measurement data were taken on the S-807 for the final report this quarter. Compilation of additional data and a rough draft of the final report are the objectives for next quarter.

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1 Marietta, Georgia

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Radio Corp. of America
75 Varick St.
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Radio Corp. of America
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P.O. Box 205
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Sylvania Electronic Systems
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